2016 SPECIAL REQUEST FULL PROPOSAL
Fertilizer Research and Education Program, California Department of Food and Agriculture

Understanding Influences on Grower Decision-Making and Adoption of Improved Nitrogen Management Practices

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Executive Summary: Adoption of improved N management practices is paramount to meeting the demand of regulatory agencies to reduce N loading into surface and groundwater of California. However, there is inadequate information on the current rate of adoption and little understanding of the barriers to more complete adoption. This project aims to quantify the current use of improved practices and characterize drivers of grower behavior in order to enhance future research, education and outreach programs, and tailored policy recommendations. The findings will help guide practice, policy, investment and incentives necessary to meet California's agricultural and environmental challenges.

Our objectives are: 1) to develop a qualitative understanding of key influences and barriers to adoption of improved N management practices in the regions represented by the San Joaquin County & Delta Water Quality Coalition (SJDWQC) and the East San Joaquin Water Quality Coalition (ESJWQC); 2) to distribute, collect and aggregate survey data from growers; 3) to analyze both qualitative and quantitative response data to determine key motivations and barriers to grower adoption of improved N management practices; 4) to communicate these findings directly with the grower communities in which we work, as well as academic and regulatory body audiences; and 5) to outline and recommend potential incentives targeted at different segments of the grower population in order to craft more effective programs. In addition, we will collaborate with the South San Joaquin Water Quality Coalition at all stages of the project in order to expand benefits to other regions. The SSJWQC's will provide regional data and input to our process to ensure that our project activities will have widespread relevance to all growers in the Central Valley.

Our team brings superb capabilities in the required research methodologies, extensive understanding of agricultural N management strategies, and an excellent reputation among growers and stakeholders. Collaborating with the Water Coalitions will greatly simplify grower participation and enhance our ability to interpret results. To maximize grower participation all results will remain anonymous and multiple avenues for participation will be provided. Our approach includes semi-structured interviews with growers and advisors, and focus groups with interactive surveys and roundtable discussions between grower members. Results of this process will be used to develop the subsequent coalition wide survey and to help interpret the findings. The process will allow for a high degree of site, crop and grower specificity of results.

Quantifying current practices provides a baseline for measuring progress. Identifying barriers to adoption provides a framework for improved outreach, more focused research and innovation and guidance for policy development. Outlining and recommending potential incentive mechanisms targeted at different segments of the grower population suggests paths forward to

work toward reducing and overcoming current barriers to adoption. This information is critical for both producers and regulators as they strive to meet the challenge of reducing N loading into ground water while sustaining the profitability of Californian agriculture.

Justification

Problem

Adoption of improved nitrogen (N) management practices by California growers is a required step in reducing N movement into surface and groundwater and maintaining economically viable cropping systems, while satisfying the Irrigated Lands Regulatory Program (ILRP) requirements. Research over the past decade has identified many promising practices that can improve N management and maintain economically viable cropping systems. These practices include the use of N budgets to balance N inputs and outputs for individual field units; implementation of the "4R's" (right rate, time, place, and source) to guide fertilization strategy; the use of leaf and soil N sampling for verification of crop nutrient status and residual soil N; appropriate integration of fertilizers with irrigation; enhancing soil health to improve nutrient retention; and careful deployment and management of micro-irrigation systems for efficient water use. Many of these practices have associated benefits for soil health and climate-smart agriculture. Despite progress in the development of improved N management practices, there is insufficient understanding regarding the current rate and barriers to practice adoption.

Recent research has suggested a number of possible factors influence grower decision-making, including perceptions of risk, economic and labor constraints, social norms, sources of trusted information, social capital and networks, farm characteristics including size and income, and participation in local policy forums. However, we do not currently have a robust understanding how these factors relate to adoption rates of improved N management practices across the diverse geographies and grower demographics of the Central Valley. This includes the role of different types of policy tools and outreach strategies for changing farmer behavior and attitudes.

The general orders for irrigated lands require development of Management Practices Evaluation Plans (MPEPs) to evaluate and measure progress toward adoption of improved practices and reduced flow of N to surface and groundwater. Inherent in these MPEPs is the requirement to identify beneficial practices, to adapt these practices to specific site/crop/grower characteristics and to provide a strategy to measure progress toward achieving these goals. Much progress has been achieved in identifying improved technical solutions has been achieved by research and extension personnel at the University of California, the CSU system, USDA-NRCS, commodity groups and industry funded programs. However, we do not currently have good strategies to determine rate of adoption of improved practices nor to identify the general or specific constraints to adapting specific practices for given site or grower contexts. Furthermore, we do not currently have an established baseline of practices against which to measure progress.

This project aims to (i) develop an understanding of the current status of grower adoption of improved N management practices, (ii) determine the key influences on grower decision-making, and (iii) identify the key incentives and barriers to enhanced adoption of improved management practices. The information developed will inform stakeholder groups including regional Water Quality Coalitions, UC Extension, private consultants, State Water Boards, commodity groups and others to inform policy-making and improve N management.

FREP Mission and Research Priorities

This project addresses the research priority area of "Addressing Challenges and Barriers to Improving Management Practices". Our work will evaluate the factors influencing grower decision-making and adoption of improved N management practices. While practices such as N budgeting, the 4R's, leaf sampling and improved fertigation have contributed greatly to improved N management, full adoption of these strategies across irrigated agriculture cannot be realized without understanding the factors that influence and constrain grower decision-making. Furthermore, future strategies to improve N management practices will also require improvements in soil health to enhance root zone N retention and root health. These soil health practices may include cover cropping, conservation tillage, crop rotation, and establishing perennial plantings with hedgerows or buffer strips around field edges and riparian corridors, all of which are being explored for their potential contribution to recovering and fixing excess soil N, reducing nitrous oxide emissions, improving nutrient and water retention on fields, sequestering carbon in soils, and broadly, building a "climate-smart" agricultural sector. Investigating rates of current adoption and barriers to enhanced adoption of these broad multi-benefit soil health practices will help understand how this 'next phase' of agro-ecosystem management may evolve. This knowledge gap will assist FREP, NRCS and CDFA in developing and implementing effective incentive programs that will encourage an important subset of growers to explore these approaches.

Impact

Progress toward meeting California's water quality mandate, as defined in the ILRP, is a fundamental requirement for the sustainability of agriculture in California and the protection of California's environment. Thus, by understanding barriers to adoption of N management and soil health practices, this project will have substantial impact on California's agricultural sector.

Waste discharge requirements (WDR Orders) require that agricultural producers in California develop practices that are protective of groundwater quality. Regional Water Boards require Water Quality Coalitions (representing growers throughout the state) to conduct MPEPs that identify improved N management practices that can be implemented to protect groundwater quality. Additionally, these Coalitions prepare and implement mandatory regional water quality management and monitoring plans and report the results to the State Water Boards. All member growers are required to submit information to their coalition, including a farm evaluation of practices currently in use and a certified N management plan that includes crop N outputs, applied N fertilizers, applied organic N materials and adjustments for N credits, including residual soil N and N in irrigation water.

The proposed project directly addresses the needs of these Coalitions by quantifying current practice use and determining what influences grower adoption of improved N management practices. We have direct collaboration on this project with the San Joaquin County and Delta Water Quality Coalition (SJDWQC) and the East San Joaquin Water Quality Coalition (ESJWQC). These Coalitions include areas that are highly vulnerable to nitrate contamination and represent a diverse cross-section of California's agriculture in terms farm sizes and types of annual and permanent crops. Throughout this project, we will collaborate with Southern San Joaquin Valley (SSJV) MPEP Committee representing seven SSJV Water Coalitions. We will immediately share our methodologies, technologies and results so that the SSJV MPEP can adapt and extend our approaches to the SSJV region. These collaborations allow us to reach essentially all irrigated agriculture in the San Joaquin Valley. All data collection and analysis tools

developed will be made available open-access to facilitate their use in other regions across the state.

This project will provide critical baseline information against which progress toward meeting legislative mandates can be measured. Furthermore, this project will provide an understanding of the barriers to grower adoption and hence guide future research, outreach and design of policy and incentive programs. Currently the Water Boards of California are developing the monitoring strategies that will demonstrate progress toward meeting California's water quality standards. While this project will not replace the need for groundwater monitoring in high vulnerability regions it will provide a supplemental methodology that will be highly valuable in regions where groundwater monitoring is not practical and will allow for a determination of efficacy of research and outreach activities.

Long-Term Solutions

Currently, we have many tools that can contribute to improved N management and comprehensive soil health practices for a majority of crops in California; however, the utilization of these practices is constrained by our limited knowledge of the factors that influence grower decision-making and adoption of these practices. Using the East San Joaquin Valley and Delta as case studies, and through partnerships with the SSJV MPEP, this project will provide measurable progress toward meeting California's water quality and climate challenges and better target outreach and direct research activities to optimize practices and technologies. Furthermore, the project will allow us to develop an initial understanding about the potential synergies between N-management, soil health, and climate-smart agriculture. Practices that provide economic benefits to the grower and multiple environmental benefits are more likely to be adopted and contribute to long-term sustainability.

Related Research

There has been a tremendous amount of research and outreach conducted over the past decade to optimize N management practices in agricultural lands of California by our research group, along with many others. The majority of this research has focused on understanding the biological basis for N use by plants, the engineering of practices and technological tools to optimize N delivery, and monitoring practices required to measure outcomes. Additionally, our research team has been critical in developing early understandings of grower behavior and decision-making utilizing survey and interview methodologies (Niles et al. 2013, 2014, 2015, Lubell et al. 2014). However, there has been little research conducted to measure the extent of grower adoption of improved N management practices or investigate influences to decision-making and barriers to N management practices.

Multiple recent studies, many of them FREP funded, have explored improved N management practices in annual and permanent cropping systems. Muhammad et al. (2015) identified in-season patterns of N accumulation in fruit and optimum N rates to match almond fruit N demand. Saa et al. (2014) developed tools to predict almond leaf N from early season samples allowing for in-season N management decisions. Alsina et al. (2013) reported significantly greater N_2O emissions in almond from drip irrigation compared to microsprinklers. Schellenberg et al. (2012) demonstrated significantly greater peak N_2O emissions from different N fertilizer sources during summer fertigation. Baram et al. (2016) conducted a study to explore current and alternative irrigation and fertigation practices and found that reduction of N losses to groundwater would require better control of fertigation amounts and irrigation duration. Annual

crops like tomato, lettuce and strawberry have also experienced improvements in N management practices. Hartz and Bottoms (2009) developed growth-response curves that show the accumulation of tomato N biomass during the growing season to aid with timing N fertilizer application. Similar advances in monitoring N biomass accumulation in lettuce using leaf N tissue analysis have been developed to help time fertilizer applications (Bottoms et al. 2012). Bottoms et al. (2013) also identified effective rotations from vegetables into strawberry and showed adequate residual soil N to satisfy the strawberry crop demand during winter. Many row crops including cotton have adopted conservation tillage, which can improve soil organic carbon and internal N cycling of soil (Mitchell et al. 2007).

Impediments to adoption of new practices can be highly varied and diverse based on region and crop type, but may include problems of trust or integrity of the informational source, perceived added costs or increased risks, lack of appropriate technology or training, constraints on water delivery or distribution, lack of time or resources, among many others. A recent USDA study, "Conservation-Practice Adoption Rates Vary Widely by Crop and Region", brought federal attention to these phenomena and expressed need for further research on barriers of adoption of new practices. The study investigated financial and demographic influences on commodity crop farmers' adoption of three specific conservation practices- cover crops, conservation tillage, and N fertilizer management. The report emphasized the understanding that economic factors are not the only influences driving farmer decision-making, even when practices produce cost-reduction benefits. Rather, the study found that adoption rates vary dramatically by crop type, field characteristics and place and argues a strong call for further research that determines factors influencing "sustained and combined" adoption of best management practices (Wade et al., 2015).

Niles et al. (2013) found that personal experiences with environmental risk (i.e. drought) led to increased adoption of adaptation practices (i.e. drip irrigation, water conservation, crop switching to drought tolerant varieties) in Yolo County farmers. Lubell et al. (2014) and Shaw et al. (2011) have shown that social networks and shared group memberships that facilitate social learning supported increased adoption rates of new sustainable practices among Lodi wine-grape growers in San Joaquin County. These studies build on a large body of scholarship on the diffusion of innovations and agricultural decision-making.

Contribution to Knowledge Base

This project offers multiple contributions to current knowledge and will generate specific new information related to N management in California's agricultural sector. Current knowledge suggests improved N management practices increase N and water use efficiency by reducing N losses. Our project will generate specific new information on grower decision-making and adoption of improved N management, as well as robust soil health practices. This knowledge will provide basis for investigating potential incentive mechanisms by which behavior change may be motivated. Understanding how factors influencing decision-making vary across the grower population will allow these incentives to be developed to uniquely address the heterogeneous barriers faced by different subsets of the grower population. This will be accomplished by assessing a host of predictor variables, including: (i) social factors- demographics, education, farming history and traditions, perceptions of environmental (i.e. drought, water quality, climate change) and economic risks, sources of information (i.e. crop advisors, Cooperative Extension specialists, industry groups, other farmers) , social networks; (ii) political factors- attitudes toward governmental programs and regulations, involvement in

local resources governance (i.e. Water Quality Coalitions, Groundwater Sustainability Agencies), historic water rights; (iii) economic factors- farm input costs, crop profitability, farm size and income, cost of practices, land owner versus tenant, accrued debt, access to capital; and (iv) local soil, climate and environmental factors. These predicted influences on decision-making will be analyzed for their impact on permanent and sustained adoption of identified improved N management practices, participation in local N management programs and regulatory bodies (including the Water Quality Coalitions), use of incentive programs to fund on-farm adaptation to improve N management, and adoption of other soil health practices to improve N retention in the root zone and root nutrient extraction.

Specific Hypotheses

(*H1*) Growers with poorer access to information through peer-to-peer relationships, farm advisors (independent consultants or Cooperative Extension), industry groups, and/or scientists will be less likely to engage in N management, including showing lower overall rates of practice adoption, participation in N management discussions and workshops, and use of incentive programs, and lower sustainment of any practices that *are* adopted.

(*H2*) The primary and trusted source of a grower's information will influence grower engagement and adoption of improved N management practices. We predict that growers who do *not* regularly work with UC Cooperative Extension, NRCS Resources Conservation Districts, private crop advisors, or other retail/ commercial producer groups, nor are active participants in Water Quality Coalitions, will be less likely to adopt improved N management practices.

(*H3*) Access to resources and power, including finances, labor, and land ownership, will be a driving factor in engagement with improved N management. We predict growers with lower financial and human capital and those who rent the land on which they grow will be less likely to adopt improved N management practices and engage with other stakeholders through forums like the Water Quality Coalition meetings and N management workshops.

(*H4*) We predict growers with ideologies that oppose government regulation or values that exclude environmental protection will be less likely to adopt improved N management practices. Delivering N-management practices through voluntary programs with framing emphasizing the on-farm (rather than environmental) benefits will be more effective for these growers.

(*H5)* Framing these N and soil management practices as directly benefiting growers in different ways (e.g. nitrogen savings, cost savings, reduced input, future returns on investment) and delivering practical information through a variety of trusted sources (i.e. UC Cooperative Extension, Industry Groups, Private Advisors) may lead to more widespread support among current non-adopters.

(H6) Smaller or less profitable farms and farmers growing on leased lands have lower capacity to experiment with new N-management practices and complete various policy requirements, and hence will be less likely to adopt N-management practices.

Measuring these complex factors will contribute to our understandings of decision-making and adoption of practices in agriculture broadly. We acknowledge and will specify various levels of adoption from adopters to non-adoptors as well as full, sustainaed, partial, or temporary adopters. Furthermore, our work will inform improved design and implementation of FREP's outreach and development of incentives to increase the efficacy of programs related to improving N management.

Grower Use

The findings of our work will greatly enhance the relevance and applicability of many of the improved N management practices that have been identified through prior research and will allow research, extension and technological solutions to be better tailored for grower use. Demonstration of these influences helps with mandatory efforts to reduce N losses and potentially increase economic returns to compliant growers and will inform future policy development. Understanding the main drivers of grower decision-making allows outreach and extension programs to develop strategies that increase the overall adoption rates of N management practices.

Objectives

Objective 1: Develop a qualitative understanding of adoption of improved N management practices in the regions represented by the SJDWQC and ESJWQC. Specific practices include: utilization of N budgets, adaptive N fertilizer application rates, sources, timing and placement (4R's), use of leaf and soil sampling, integration of fertilization with irrigation, soil quality manipulations including the use of organic matter and other amendments. Interview and focus groups will identify other possible practices for analysis. For a subset of growers who are already active in improved N management, adoption of additional soil health practices, including cover cropping, conservation tillage, crop rotation, and perennial plantings, will be assessed.

Objective 2: Distribute, collect and aggregate survey data from grower members in SJDWQC and ESJWQC regions. Quantify current practice adoption (full/partial, permanent/ temporary) and determine effects of biophysical, social, economic, and political factors on growers' decisions to adopt improved N management practices, participate in local N management discussions and workshops, and utilize incentive programs. Use results to test our hypotheses with a variety of multivariate statistical models.

Objective 3: Analyze responses to determine key motivations and barriers to grower adoption of improved N management practices and soil health practices broadly. Validate survey responses by cross-checking with regional MPEPs and grower's individual farm and N management plans.

Objectives 4: Communicate findings directly to grower populations surveyed, as well as to academics, regulatory bodies, independent crop advisors and industry groups to inform improved outreach and education by all stakeholder groups.

Objective 5: Use results from multivariate statistical analyses to identify key variables influencing practice adoption in distinct subsets of the grower population that could be targeted through tailored incentive programs. Outline potential specific outreach programs and policy incentives that could be used to improve practice adoption.

Work Plans and Methods

Geographic, biophysical and demographic information for all respondents will be obtained in an anonymous format and used to interpret results and develop context specific solutions. The anonymity of all respondents will be maintained through all activities.

Work Plans

Objective 1: Qualitative understanding of adoption of improved N management practices

Task 1.1: Conduct ~10 semi-structured interviews with innovative growers in each of the SJDWQC and ESJWQC regions to better understand their use of N management practices and the social, political, and economic factors influencing adoption of practices. (Winter 2017)

Task 1.2: In conjunction with regular SJDWQC and ESJWQC meetings, host voluntary grower focus groups, real-time surveys (i.e. participants respond anonymously using "clickers") and roundtable discussions. We will quantify which practices are most in use in each region and why, perceived costs and benefits of each used and unused practice, greatest challenges to adopting new practices, additional soil health practices that appeal for multi-benefit purposes, sources of information most important in each region and their opinions on effective N management practices. (Winter-Spring 2017)

Task 1.3: Conduct semi-structured interviews with key farm advisors and Water Quality Coalition representatives identified by growers as important and trusted sources of information or otherwise influential figures on N management issues. Discuss their roles in regional N management; perceptions on the ILRP program, improved N management and soil health practices, and the role of the water quality coalitions; the biggest challenges their growers face when adopting new N management practices. (Spring 2017)

Objective 2: Survey growers in SJDWQC and ESJWQC regions to identify adoption of N-management practices and key decision-making influences

Task 2.1: Design survey instrument based on Task 1, to assess social, political and economic factors influencing decision-making and adoption of improved N management practices. The survey will include questions regarding different levels of N management practice implementation, participation in available policy initiatives and outreach/extension programs, communication with agricultural stakeholders (e.g. government agencies, non-governmental organizations, crop/pest control advisors, producer associations, and other farmers), attitudes towards N management issues, and basic operator/operation characteristics. Assemble Survey Advisory Committee (SAC) from Project Supporters and representatives of key stakeholder groups (i.e. growers, industry groups, Farm Bureau, etc). (Summer 2017)

Task 2.2: Survey Review: SAC reviews first draft of survey; revise according to reviews. Pilot second draft of survey instrument with a small group of growers in each region to test the efficacy of the question design and structure to elicit desired information. Revise again if needed. (Late Summer-Fall 2017)

Task 2.3: Develop strategy for identifying appropriate grower sample, survey distribution method (mail and/or internet) and outreach activities in each region, coordinating with Water Coalitions and/or other advisory groups (i.e. Cooperative Extension, RCDs, Farm Bureau). (Fall 2017)

Task 2.4: Deliver survey to all growers within SJDWQC and ESJWQC regional areas, using best available membership lists identified in Task 2.3. Alternate survey strategies will also be considered as appropriate (Winter 2018)

Objective 3: Analyze survey responses to inform outreach, education and incentive programs

Task 3.1: Develop descriptive analysis of compiled results and emerging trends from interview, focus group and survey data, leading to at least one peer-reviewed paper. (Spring 2018)

Task 3.2: Use multi-level hierarchical modeling with random effects and factor analysis on survey response data to determine key variables influencing grower decision-making and adoption of N management practices in each region, leading to at least one peer-reviewed paper. (Summer 2018)

Task 3.3: Using unidentified grower information, correlate survey responses on practice adoption with submitted farm N management plans and regional MPEPs. (Summer 2018).

Task 3.4: Develop a report for FREP and policy briefs that address key social, economic, and political factors influencing grower participation in N management programs and advise actions to move forward and overcome barriers to adoption of improved practices. Distribute reports through Project Supporters' respective networks. (Fall 2018)

Objective 4: *Outreach and education activities*

Task 4.1: Organize and conduct outreach activities, including workshops to present trends of adoption of improved N management practices in each region, comparison of perceived costs/ benefits of practices, and introduce resources (i.e. technical advisory services and financial incentive programs) to assist in adapting management practices. Workshops hosted in collaboration with Water Quality Coalitions and Cooperative Extension during regular Coalition meetings. Collaborate with NRCS-Resource Conservation District's "open house" visit days to highlight innovative growers who have adopted improved N management and other soil health practices that have provided cost or time-savings or other co-benefits. (Throughout 2018, continue in appropriate venues through 2019)

Objective 5: Outline and recommend potential incentives for adoption

Task 5.1: Outline and recommend programs and policy incentives that will address unique barriers experienced by different subsets of the grower population. We will use the results of multivariate analysis of practice adoption behavior to identify key variables that could be targeted by different types of outreach programs and policy incentives (See Task 3.1). These may include building financial and technical assistance programs, improving access to educational tools, developing low interest loans and cost share programs, and providing tailored technical workshops for growers and operators and sustainability training workshops for crop advisors, each of which specifically address unique needs (i.e. language translation, access to technology, geographic location of meeting, timing of meeting) of different segments of the agricultural community. These will be targeted toward subsets of the grower population who don't regularly take advantage of opportunities through other technical and financial assistance programs (e.g. USDA Environmental Quality Incentive Program or Conservation Reserve Program, CDFA State Water Efficiency and Enhancement Program, Specialty Crop Block Grant Program, etc.).

Methods

Semi-Structured Interviews with growers: On the ground supporters, particularly Dr. Michelle Leinfelder-Miles, Ben Wallace and Michael Wackman in the San Joaquin County-Delta region, and Dr. Sandoval and Parry Klaussen in the East San Joaquin region, will connect researchers to growers who are willing to participate in semi-structured interviews (1-1.5 hours long), hold varying perspectives on the N management programs and have advanced to various stages in their implementation of improved N management practices, and in some cases, more robust soil-health practices. Approximately 10 interview sessions with key growers in both the ESJWQC and the SDWQC regions will be conducted in winter 2017. Interviews will be

recorded and transcribed using nVivo qualitative analysis software. Basic qualitative analysis will identify main themes driving grower adoption of N management practices, participation in local regulatory bodies (i.e. Water Coalitions, Groundwater Sustainability Agencies) and utilization of incentives. These interviews will build contextual and nuanced ethnographic understandings of growers' perceptions on N management and water quality concerns and trusted sources of information.

Focus groups: In conjunction with a regular SJDWQC and ESJWQC meetings in winter-spring 2017, we will host 1-3 grower focus groups utilizing a real-time survey with individual clickers and recording responses with TurningPoint Software. We will follow up the survey with a breakout session structured as a roundtable discussion in which we discuss the perceived costs and benefits and major barriers to adopting improved N management and soil health practices. We will also determine who growers trust for important information on these issues, to identify the key advisors for further interviews.

Semi-Structured Interviews with agriculture advisors: Based on responses from the focus groups, we will conduct semi-structured interviews in spring 2017 with farm advisors and technical consultants to understand their knowledge, perceptions and support for N management practices and the biggest challenges they face in assisting their growers implement these practices. Interviews will be recorded and transcribed using nVivo software.

Grower Survey: In summer 2017, the survey instrument will be designed and modified for each region based on the contextual understandings reached through the interviews and focus groups. The SAC will be assembled from the Project Supporters and other key stakeholders in each region (i.e. important agriculture advisors identified in focus groups, innovative growers, industry representatives, Farm Bureau) and will review the survey instrument for structure and appropriateness of questions. After revision based on advice from the SAC, the survey will be distributed by mail in late summer 2017 to a small pilot group of growers who have agreed to test the instrument. Responses will be analyzed for efficacy of eliciting the desired information and survey revisions will be made if needed. With advice from the SAC, we will identify the appropriate grower sample and distribution method for the survey, possibly in collaboration with the regional Water Quality Coalitions and/or other advisory groups (i.e. Cooperative Extension, RCDs, Farm Bureau, producer groups). The final draft of the survey will be reviewed again by the SAC before being distributed to growers in winter 2018 using the best determined membership mailing list. We will follow the Dillman (2009) method, of introductory and reminder postcards for mail-out surveys, with extensive outreach to our partners in each region to improve our response rates. PI Dr. Mark Lubell and Supporter Dr. Meredith Niles has extensive experience developing and fielding grower surveys in California, including previous work on the irrigated lands program, rangeland management, climate change, and various other projects.

Analysis: Survey data and response rates will be assessed for accuracy and analyzed using R Statistical Software. We will identify key predictor variables influencing practice adoption, participation in N management discussions and workshops, and use of incentive programs (response variables) using factor analysis and construct hierarchical multi-level random effect models to run comparisons that control for regional differences, which will allow us to estimate the magnitude of influence of each key predictor variable. We will also apply social network analysis to identify how trusted key information sources are related to one another and vary based on farm and farmer characteristics within each region. Finally, we will correlate

unidentified survey responses with farm N management plans and compiled averaged survey responses from each region with regional MPEPs to both validate survey data and understand differences between intended and actual actions. This innovative step will both address survey validation needs and help to understand discrepancies between suggested and actually adopted changes to N management in each region.

Outreach on Results: We will interpret and present these results back to the SAC, growers via the Water Quality Coalition meetings, and to the FREP. Additionally, we will write and publish a summary report for the FREP, policy briefs to be distributed through Project Supporter's networks of growers and agriculture advisors, and peer-reviewed publications for Cooperative Extension and academic audiences.

Experimental Sites: This project focuses on the regions covered by the ESJWQC and the SJDWQC, which collectively represent over 1.2 million acres and 7,900 grower members farming more than 55 different crops in the Central Valley (Figure 1). The ESJWQC features level valley ground and foothills farmed on multiple different soil types. The major crops include almond, grape and tomato. The ESJWQC 2015 Annual Report described rates of improved N management practices in use on the 696,156 irrigated acres in the Coalition: 45-48% of growers used tissue and soil N testing, 46% using split application fertilizer regimes, 21% planted with cover crops. Significant biophysical challenges facing agricultural production include high soil salinity, groundwater depletion, and erosion and sediment control. Factors hypothesized to influence grower adoption of these and other improved N management practices remains unknown and unstudied. The region encompasses a broad diversity of grower demographics and production practices, which helps make results relevant to the many diverse agricultural regions across California.

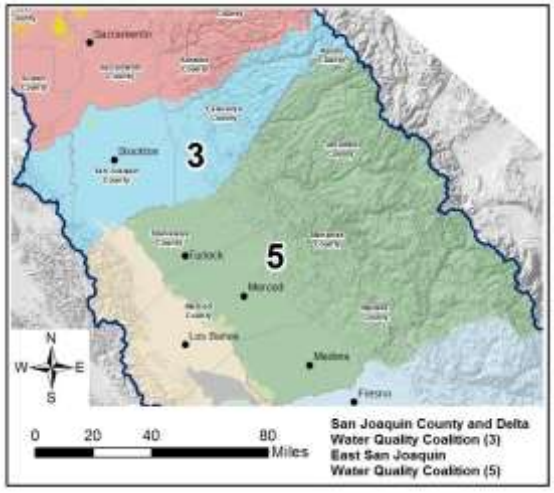

Figure 1: Study Regions

The region served by the SJDWQC includes approximately 459,000 irrigated acres, primarily lying within the low-elevation Sacramento-San Joaquin Delta. The Delta region features a complex mix of agriculture, urban development, and natural environment land uses, including the vulnerable levees protecting raised peat soil "islands" from flooding and sea level rise. The Delta plays a crucial role in transporting more than 50% of the state's average annual streamflow, while its farming lands are at high risk of flooding, land subsidence, saltwater intrusion, and urban development. The most profitable crops in the region include grapes, walnuts, almonds, cherries, alfalfa, and processing tomatoes. While baseline rates of adoption of N and soil management practices have not yet been assessed, the Coalition did report in 2013 that N fertilizer usage had significantly increased between 1990-2008, though both indirect and direct N_2O emissions decreased on an average 25 % over the same time frame. Jackson et al. (2011) concluded that altered irrigation and fertigation treatments, conservation tillage, and cover crops offer the greatest opportunity for improving on water quality challenges and reducing N_2O emissions. The Coalition has the highest participation rates in the Central Valley, perhaps because of its substantial efforts to keep membership costs very low; however, growers

continue to express concern over the challenges of meeting the new regulations due to additional imposed paperwork and overhead costs.

The diversity of these coalitions makes the ESJWQC and the SDJWQC ideal cases to compare. The ESJWQC and the SDWQC have agreed to support this project by actively integrating our project activities into their ongoing meetings and communications with growers in their coalitions. This integration of activities provides for great efficiency and reduces the burden on growers to attend additional meetings and complete additional survey requests. The WQC's will also provide (unidentified) information on grower demographics, crops, and geography that will be important in determining the core drivers of behavior and validating survey responses.

Project Management, Evaluation, and Outreach

Management: Project leaders Dr. Mark Lubell and Dr. Patrick Brown will coordinate the project with Jessica Rudnick, Graduate Student Researcher in Dr. Lubell's lab and Dr. Sat Darshan Khalsa, Postdoctoral Scholar in Dr. Brown's lab. Ms. Rudnick will be responsible for the experimental design, conducting interviews with individual growers and agricultural advisors and organizing focus groups in collaboration with the Water Quality Coalitions, designing the survey instrument, data collection and organization and analysis. Dr. Khalsa will be responsible for coordinating with the supporters, conducting outreach events on schedule and with appropriate stakeholder audience groups, data collection and analysis and report writing. Dr. Lubell offers his expertise in survey design and implementation. Dr. Brown offers his expertise in development of improved N management practices, outreach and education. Project supporter Dr. Meredith Niles offers her expertise in understanding influences on growers' adoption of practices, designing and conducting grower focus groups, designing and analyzing data collected from the grower survey.

Michael Wackman supports the project by connecting the researchers with members of the SJDWQC and Mr. Parry Klassen's will help connect with members of the ESJWQC. Mr. Ben Wallace will offer support by connecting the researchers with the Resource Conservation Districts working within the Delta region counties and with other agricultural interest groups (e.g. the Farm Bureau) working closely with growers in the Delta. The Contra Costa RCD is also conducting collaborative work to investigate the use and motivation for adoption of other soil health practices across the Delta. Dr. Michelle Lienfelder-Miles will provide support by reviewing interview, focus group, and survey materials, assisting in facilitating focus groups in the Delta, and connecting researchers with key growers and agricultural advisors in the Delta region for preliminary qualitative interview work. Dr. Sam Sandoval will provide contextual knowledge of practices and perceptions in the San Joaquin Valley, review survey materials, and facilitate grower relationships. Casey Creamer, coordinator of the SSJ MPEP committee will support the program by participating in project development and implementation stages and provision of SSJ MPEP data for comparative analysis and interpretation.

Support from non-governmental organization partners, including Environmental Defense Fund and Climate Action Reserve, offer insights and perspective on incentive program design and policies related to developing carbon market offsets and the Greenhouse Gas Reduction Fund. These partners already work extensively on linking agricultural practices to carbon markets and other climate-policy incentives.

Evaluation: We will assess the response rates of growers to our initial exploratory work,

including survey response, focus group attendance and post-survey outreach meeting attendance, and grower attendance during designated time slots at the Water Coalition meetings. We will monitor how and which growers interact and actively participate with our interactive survey (clicker questions) and roundtable discussions, aiming to build inclusive environments where diverse viewpoints feel welcomed and heard. After our initial exploratory work, we will proceed with our survey approach and will consider success on the project to be a 30% survey response rate (based on response rates to previous surveys). We will use our validation approach to correlate survey responses with farm N management plans and regional MPEPs to understand how much variation exists between intended and actual adoption of practices. We will also be able to use this information validate identified barriers to adoption.

We will assess the value of our educational tools and outreach efforts by attendance at workshops, spread and readership of our distributed report materials, and engagement and response to work toward overcoming identified barriers to adoption. The diverse group of project supporters will facilitate broad engagement and effective outreach of our findings.

Finally, our data collection on current adoption of practices will provide a baseline from which to compare future adoption rates after recommended incentive programs are implemented. This will provide an opportunity to test the efficacy of various incentive structures under different conditions and will provide feedback to the recommendations that are made based on these research findings.

Outreach: Grower communication occurs in a number of venues in each region, including Water Quality Coalition meetings, Farm Bureau meetings, N management workshops and certifications, NRCS-RCD best management practice open-houses, and Cooperative Extension workshops and focus groups. We will develop presentations and policy reports to present in as many of these venues as possible. One strong communications outlet is through the Water Quality Coalitions, who have identified a number of meetings that are mandatory for their grower members to attend. Each coalition will hold 3 general overview meetings each during 2017 and again in 2018. Coalitions also host N certification classes, along with individual crop-oriented meetings, groundwater management planning meetings and watershed specific meetings. Our supporters in these coalitions have agreed that our team can use these meetings to conduct outreach activities including, but not limited to, overview seminars of our work, interactive survey sessions with grower members, marketing our surveying efforts, and reporting our survey and analysis results.

Additionally, we will share results with certified crop advisors as a part of our ongoing trainings with UCANR Water Institute and the California Association of Pest Control Advisors and through a wide variety of commodity group, UCANR, FREP and other organizations. Furthermore, we will publish and distribute policy briefs through our project supporters' networks and publish peer-reviewed articles in focused journals like *California Agriculture,* as well as broad-reaching interdisciplinary journals like *Ecology and Society* and *Global Environmental Change.*

Budget Narrative

Personnel Expenses

Principal Investigator, Dr. Mark Lubell commits 2% of his annual effort to the project for the full duration of the project. No funds are requested to support his effort because it will be an in-kind contribution by the university. Advise on research design, including survey design and delivery.

Help analyze and write-up survey results for policy reports, outreach presentations, and academic publications.
Co-Principal Investigator, Dr. Patrick Brown commits 2% of his annual effort to the project for the full duration of the project. No funds are requested to support his effort because it will be an in-kind contribution by the university. Advise on specific N-management practices that should be focus of survey. Coordinate with commodity groups, Water Coalitions, extension specialists and others on project execution. Participate in focus group and interview activities. Help analyze and write-up survey results for policy reports, outreach presentations, and academic publications.
Project Scientist, Sat Darshan Khalsa: Funds are requested to support the Project Scientist at 33% effort for the full duration of the project. Advise on specific N-management practices that should be focus of survey. Coordinate with commodity groups, Water Coalitions, extension specialists and others on project execution. The total funds requested $58,314.
Graduate Student Researcher, Jessica Rudnick: Funds are requested to support 1 Graduate Student Researcher at 50% during the 6 academic quarters (including tuition) and at 100% during the 2 summer quarters. Advise on research design, including survey design and delivery. Help analyze and write-up survey results for policy reports, outreach presentations, and academic publications. Conduct personal interviews and deliver survey. The total funds requested $54,316.

Operating Costs

Supplies: A total of $12,000 requested for materials and supplies such as mailing supplies for survey.
Travel: Funds requested to cover in-state travel expenses associated with site/field visits. We are estimating that we will need to complete about 20-24 trips per year to our field sites. The costs are estimated based on round-trip mileage from Sacramento/Davis area to Fresno Area, an average of 400 miles roundtrip at $0.575 per mile = $230 per trip x 12 trips, and from Sacramento/Davis and to Stockton Area, an average of 200 miles roundtrip at $0.575 per mile = $115 per trip x 11 trips. Depending on the task at the hand, the PI, Co-PI, or Project Scientist will be making site visits. The total funds requested $8,000.
Professional/Consultant Services: Total funds requested $10,000 for data entry and survey design consulting.

Other Expenses

Student Tuition and Fees*:* Funds requested to cover in-state student tuition and fees for 1 Graduate Student Researcher. The costs are reflective of the 25% tuition buydown program implemented by the university. Total funds requested $27,690.
Indirect Costs*:* An indirect rate of 25% is applied to a base of Modified Total Direct Costs. The rate is in accordance with California Education Code 67327 and is part of the MOU between UCOP and the State. Total funds requested $33,158.

References

Alsina M.M., Borges A., Smart D.R. (2013) Spatiotemporal variation of event related N2O and CH4 emissions during fertigation in a California almond orchard. Ecosphere 4:1-21.

Bottoms T.G., Smith R.F., Cahn M.D., Hartz T.K. (2012) Nitrogen requirements and N status determination of lettuce. HortScience 47.

Bottoms T.G., Hartz T.K., Cahn M.D., Farrara B.F. (2013) Crop and soil nitrogen dynamics in annual strawberry production in California. HortScience:1034-1039.

Baram S., Couvreur V., Harter T., Read M., Brown P.H., Hopmans J.W., Smart D.R. (2016) Assessment of orchard N losses to groundwater with a vadose zone monitoring network. Agric Water Manage 172:83-95.

Dillman D. A., J. D. Smyth, and L. M. Christian. 2009. Internet, Mail and Mixed Mode Surveys: The Tailored Design Method, 3rd edition. John Wiley: Hoboken, New Jersey. 499.

Hartz T.K., Bottoms T.G. (2009) Nitrogen requirement of drip-irrigated processing tomatoes. HortScience 44:1988-1993.

Jackson, L., Wheeler, S. Holland, A., O'Geen, A. 2011. Case study on potential agricultural responses to climate change in a California landscape. Climatic change 109.1: 407-427.

Lubell, M., Niles, M., Hoffman, M. 2014. Extension 3.0: Managing agricultural knowledge systems in the network age. *Society and Natural Resources.* 27: 10, 1089-1103.

Mitchell J.P., Klonsky K., Shrestha A., Fry R., DuSault A., Beyer J., Harben R. (2007) Adoption of conservation tillage in California: current status and future perspectives. Australian Journal of Experimental Agriculture 47:1383-1388.

Muhammad S., Sanden B.L., Lampinen B.D., Saa S., Siddiqui M., Smart D.R., Olivos A., Shackel K.A., DeJong T., Brown P.H. (2015) Season changes in nutrient content and concentrations in a mature deciduous tree species: Studies in almond (Prunus dulcis (Mill.) D.A. Webb). European Journal of Agronomy 65:52-68.

Niles, M.T., Lubell, M. and Brown, M. 2015. How limiting factors drive agricultural adaptation to climate change. Agriculture, Ecosystems & Environment 200: 178-185.

Niles, M. T., Lubell, M. and Haden. V.R. 2013. Perceptions and responses to climate policy risks among California farmers. Global Environmental Change 23:1752–1760.

Saa S., Brown P.H., Muhammad S., Olivos-Del Rio A., Sanden B.L., Laca E.A. (2014) Prediction of leaf nitrogen from early season samples and development of field sampling protocols for nitrogen management in almond (Prunus dulcis [Mill.] DA Webb). Plant Soil 380:153-163.

Schellenberg D.L., Alsina M., M., Muhammad S., Stockert C., M., Wolff M., W., Sanden B.L., Brown P.H., Smart D.R. (2012) Yield-scaled global warming potential from N2O emissions and CH4 oxidation for almond (Prunus dulcis) irrigated with nitrogen fertilizers on arid land. Agriculture, Ecosystems and Environment 155:7-15.

Shaw, L. and M. Lubell. 2011. The evolution of local partnerships for sustainable agriculture. Society and Natural Resources 24:1078–1095.

Wade, T., Claassen, R., and Wallander, S. 2015. Conservation-Practice Adoption Rates Vary Widely by Crop and Region. EIB-147. United States Department of Agriculture, Economic Research Service.